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MBA PROFESSIONAL REPORT

Selection Methodology of H-1 Components as Potential Candidates for Performance Based Logistics Contracts

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December 2008

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SELECTION METHODOLOGY OF H-1 COMPONENTS AS POTENTIAL CANDIDATES FOR PERFORMANCE BASED LOGISTICS CONTRACTS

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Submitted in partial fulfillment of the requirements for the degree of

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SELECTION METHODOLOGY OF H-1 COMPONENTS AS POTENTIAL CANDIDATES FOR PERFORMANCE BASED LOGISTICS CONTRACTS

ABSTRACT

The purpose of this planned project is to devise a method to evaluate H-1 components as possible candidates for Performance Based Logistics contracts. The objectives of this project are: (1) provide an overview of the H-1 program; (2) provide an overview of Performance Based Logistics contracts for component support; and (3) explore methods of identifying components as PBL candidates specifically for the H-1 community, through an analysis of readiness data, interviews with subject matter experts and use of Crystal Ball® as a forecasting mechanism.

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LIST OF ABBREVIATIONS AND ACRONYMS

3PL	Third Party Logistics
AAMO	Assistant Aircraft Maintenance Officer
ACE	Air Combat Element
AH	Attack Helicopter
AMO	Aircraft Maintenance Officer
APU	Auxiliary Power Unit
Ao	Operational Availability
BCM	Beyond Capable Maintenance
CANN	Cannibalization
CAS	Close Air Support
CCAD	Corpus Christi Army Depot
DAU	Defense Acquisition University
DLA	Defense Logistics Agency
DMMH	Direct Maintenance Man-Hour
DoD	Department of Defense
DPML	Deputy Program Manager for Logistics
FCF	functional check flight
FIRST	F/A-18 E/F Integrated Readiness Support Teaming
FST	Fleet Support Team
GCE	Ground Combat Element
GSAA	Globemaster Sustainment Aircraft Availability
GWOT	Global War on Terror
HML/A	Marine Light Attack Helicopter
HOGE	Hover Out of Ground Effect
ICRL	Individual Component Repair Listing
I-level	Intermediate Level
IMA	Intermediate Maintenance Activity
IOC	Initial Operation Capability
IPT	Integrated Product Team

IWST	Integrated Weapon Support Teams
LRT	Logistics Response Time
MALS	Marine Aviation Logistics Squadron
MEU	Marine Expeditionary Unit
MICAP	Mission Capable
MMCO	Maintenance Material Control Officers
NAVICP	Naval Inventory Control Point
NAVSUP	Naval Supply Systems Command
NMC	Not Mission Capable
NMCM	Not Mission Capable Maintenance
NMCS	Not Mission Capable Supply
MTBF	Mean Time Between Failures
NALCOMIS	Naval Aviation Logistics Command/Management Information System
NAVAIR	Naval Air Systems Command
NSN	National Stock Number
OEM	Original Equipment Manufacturer
OP	Operational Performance
OPEVAL	Operation Evaluation
PBA	Performance Based Acquisition
PBL	Performance Based Logistics
PC	Production Control
OFPP	Office of Procurement Policy
PCO	Production Control Officer
POC	Point of Contact
PPP	Public-Private Partnering
QDR	Quadrennial Defense Review
RCM	Reliability Centered Maintenance
REM	Removed
ST	Singapore Technologies Aerospace
TMS	Type Model Series
TUAV	Tactical Unmanned Aerial Vehicle

UH	Utility Helicopter
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy

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Dr. Doerr,

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Major Miguel Ayala	H-1 IWST NAVICP
Rocky Kessenger	Senior Aircraft Data Analyst, FST Cherry Point
GySgt Mike Gauthier (Ret.)	H-1 Class Desk, MCAS New River

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EXECUTIVE SUMMARY

The purpose of this study was to provide a background of the H-1 program and performance based logistics and to ultimately find a methodology that would enable contracting personnel to select components that are good candidates for PBL contracts within the H-1 program.

The H-1 community has existed since the Vietnam era and the latest upgrade contract was issued in 1996. Currently, DoD has a PBL contract with Bell Helicopter Textron, Inc. PBL contracts are the preferred method of acquisition within DoD and currently there are PBL contracts on eleven part families containing twenty-one NSNs. However, there is no standard methodology used to select which components are used in PBL contracts.

In order to determine which component was a good candidate for further exploration, the authors gathered data from NAVICP Philadelphia including reports listing the top ten NMC components. The authors then looked at the NMCM, NMCS, DMMH, BCM, CANN and Support Cost categories to select the component for further evaluation. The selected component is the dual hydraulic actuator.

The authors used reports listing the removal hours on each of the dual hydraulic actuators. The data was entered into a Crystal Ball model. This model used the actual data to forecast the removal time for 10,000 of these parts. Using the results from this model, in conjunction with knowledge and experience about the aircraft and this component, the authors were able to make conclusions regarding the dual hydraulic actuator and whether or not it is a good candidate for a PBL contract.

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I. H-1 HISTORY

A. PROGRAM HISTORY

The H-1 community has existed since the Vietnam Era. Several upgrades to the UH (Utility Helicopter) and AH (Attack Helicopter) models have been made throughout the years. The current configurations of the UH and AH were initially fielded in 1970 and 1986, respectively. As these airframes reach the end of their service life, especially the UH-1N, they become increased logistic and maintenance burdens to the fleet. Specific problems include multiple modifications that negatively affect payload and power capabilities—problems that are magnified by the location of current operations in Iraq. Based on the author's observations while working as a Maintenance Material Control Officer, the modifications have also caused increased aircrew and maintainer workload. To address these issues, Bell Helicopter Textron, Inc. was awarded the H-1 Upgrade Program contract in 1996. This contract marked the beginning of the H-1 remanufacture initiative to drastically improve the aging UH and AH aircraft. The following enhancements were identified as part of the upgrade initiative:

- Improved mission capability
- Increased performance and maneuverability
- Additional survivability features
- Reduced pilot workload
- Potential for growth (Davidovich and Myers, n.d.)

Additional improvements formed as requirements to meet the demands of future missions, which include:

- Operations at greater ranges and with larger payloads
- Command, control and communications interoperability
- Expanded night and reduced visibility operations
- Improved targeting sensors and weapons
- Survivability enhancements (Davidovich and Myers, n.d.)

B. MISSION NEED

The UH-1N and the AH-1W type model series aircraft make up the composition of the Marine Light Attack Helicopter (HML/A) Squadron. The HML/A squadron's primary mission is to provide Close Air Support (CAS) to the Ground Combat Element (GCE); it also performs numerous supporting missions for the GCE and Air Combat Element (ACE). These missions include but are not limited to: air reconnaissance, armed escort, search and target acquisition, and destruction of hardened and armored targets (PMA-276, AH-1W "Super Cobra," n.d.). In addition, the UH-1N utility helicopter provides a means for command and control and is capable of fulfilling medical evacuation, control and coordination for assault support operations, raids and tactical recovery of aircraft and personnel (PMA-276, UH-1N "Iroquois," n.d.). The UH-1Y and AH-1Z, the respective upgrades to the UH-1N and the AH-1W, will continue to perform these missions. Improved capabilities will give these airframes longer on-station times and increase their payload, while extending the battle space beyond current boundaries.

C. MAJOR REQUIREMENTS

The H-1 Upgrade Program initially called for the remanufacture of 180 AH-1W and 100 UH-1N helicopters to an advanced configuration (AH-1W/AH-1Z Super Cobra, 2008). Remanufacturing efforts shifted focus following the induction of only seven AH-1Ws and six UH-1Ns into the remanufacture program due to airframe unavailability. Operational commitments in Iraq and Afghanistan prevented deploying squadrons from losing airframes to the upgrade process. Also, as of April 2005 a new cabin design and certain cost-related issues had made upgrade of the UH-1Ns to the UH-1Y configuration impractical. These changes necessitated a switch from a re-manufacturing to a new product manufacturing approach for the UH-1Y.[1]

Other major program requirements include a focus on providing 84 percent component commonality between the UH-1Y and AH-1Z, in order to drastically reduce their logistical footprint and facilitate easier maintenance for the HML/A maintainers

[1] Mike Gauthier, telephone interview, 25 October 2007.

(PMA-276, UH-1N "Iroquois," n.d.). The most significant upgrade to these Type Model Series (TMS) is to the rotor system. The existing two-blade system is replaced by a new four-bladed, composite and ballistically tolerant rotor system (PMA-276, UH-1Y "Iroquois," n.d.). Based on the author's observations while working as a Maintenance Material Control Officer, other upgrades, such as threat detection and aversion equipment (countermeasure systems) on both airframes, are also critical in order to minimize loss of life in an ever-fluid battle space.

Countermeasure improvements include such features as the turned exhaust, which drastically reduces the heat signature of the aircraft because the exhaust is deflected (turned) from heating up the tail boom. This improvement was made to the AH-1W as a fit-forward initiative completed on all aircraft forward deployed to Iraq, and to all Marine Expeditionary Units (MEU) in 2006. Other countermeasure improvements include radar warning systems and infrared countermeasure systems. These modifications will broaden the capabilities of the HML/A community to provide effective CAS and will improve effectiveness of related support missions, while simultaneously providing safety from enemy weapons systems.

D. TECHNICAL CHARACTERISTICS COMPARISONS

Table 1 illustrates the technical characteristic improvements of the UH-1Y:

Table 1. UH-1 Improvement Comparison (From: PMA-276, UH-1N "Iroquois," n.d.)

UH Comparison	UH-1N	UH-1Y	Percent Improvement
Max. Gross Weight	10,500 lbs	18,500 lbs	76
Max. Internal Fuel	1,360 lbs	2,584 lbs	90
Maximum Speed	130 kts	198 kts	52
Cruise Speed	107 kts	153 kts	43
HOGE Useful Load	3,532 lbs	5,930 lbs	68
Service Ceiling	17,300 feet	20,000 feet	16
Mission Radius	110 nm	130 nm	15

The most significant improvement to the UH-1 is not illustrated in this table. The T400 twin pack engines will now be replaced by two T700 engines. The increased horsepower of the new engines provide much more output than the T400s. The upgraded engines, in conjunction with the four-blade rotor system, will add to the lift capabilities of the Marine Corps utility helicopter. Current operations in an arid, high-heat environment revealed a serious limitation of the UH-1N in achieving the necessary power to provide the appropriate lift upon take-off. Often, the crew has to perform the same mission with less equipment and firepower in order to reduce the weight in compensation for less available lifting power.

Table 2 illustrates the technical characteristic improvements of the AH-1Z:

Table 2. AH-1 Improvement Comparison (From: PMA-276, AH-1W "Super Cobra," n.d.)

AH Comparison	AH-1W	AH-1Z	Percent Improvement
Max. Gross Weight	14750 lbs	18,500 lbs	25
Max. Internal Fuel	2100 lbs	2,768 lbs	32
Maximum Speed	190 kts	222 kts	17
Cruise Speed	131 kts	142 kts	8
Service Ceiling	14,700 feet	20,000 feet	36
Mission Radius	58 nm	128 nm	121

An important characteristic that is not included in this chart is the length of the new stub-wings. The AH-1Z, in comparison to its W predecessor will have longer, stronger stub-wings, allowing for additional weapons stores without having to track the carriage of Hellfire missiles. On the AH-1W, an accounting process placed additional responsibility on maintenance administration personnel by requiring the aircrew to accurately document flight hours in which the missiles were on the wing. This requirement surfaced because the AH-1W stub-wings developed cracks at the union of the wing and the frame resulting in the need to penalize the life cycle of mounted stub-

wings by a reduction ratio of six hours for every one hour of flight. The new wings are designed to avoid that defect. Thus, the AH-1Z should also reduce the administrative overhead on the maintenance crews.

E. PROGRAM PROGRESS

The program has undergone several changes to both cost and schedule, and in addition was forced to shift from a remanufacture strategy to a new production strategy for the UH-1Y (Snakes and Rotors, 2008). The Global War On Terror (GWOT) is the driver for the schedule changes, due to the commitments placed on the UH-1N and AH-1W assets used abroad, while design considerations necessitated the strategy change for the UH-1Y. Other changes surfaced because the vendor (Bell) was not meeting the needs of the program. Management changes were made within the company and the program schedule was revised to reach Initial Operation Capability (IOC) for the UH-1Ys in September 08. However, IOC for the AH-1Z has been pushed back until fiscal year 2011. Despite the shift in the delivery schedule, four UH-1Y and three AH-1Z Lot 1 aircraft were delivered to the fleet and are currently conducting final operational evaluation (OPEVAL) testing (Kerzner, 2007).

F. MANAGEMENT ISSUES AND CHALLENGES

1. GWOT

The onset of the GWOT increased the requirements placed on fleet assets, resulting in fewer aircraft available for the induction process. This increased demand for H-1 assets forward deployed is a primary reason why the IOC has shifted to the right.

The GWOT has also placed a usage strain on the airframes/components by operating above the utilization rate the structures are designed to support. Mission requirements in the GWOT place continual pressure on H-1 logisticians to increase operational availability (Ao). However, continued operational tempo will likely cause additional strain on life-limited components, further negatively affecting the operational availability of these airframes.

2. Upgrades

The UH-1Y cabin upgrade, which eliminated the remanufacture requirement altogether due to major structural changes with the new design, mandated an entire shift in strategy for that platform. The AH-1Z, however, has not completely abandoned the remanufacture process.

3. Supportability

The challenge that lies ahead for H-1 logisticians is to increase the Ao by addressing reliability and turn-around time of the repair parts on both airframes, while simultaneously facing increased operations and the fielding of the upgrade platforms. The answer from senior logisticians within the Department of Defense is Performance Based Logistics (PBL). The H-1 community has taken the crawl, walk, run approach to PBL implementation as Performance Based Agreements (PBA) between the warfighter and the Program Manager are established.

II. PERFORMANCE BASED LOGISTICS

A. INTRODUCTION

Performance Based Logistics (PBL) is an acquisition reform that is intended to improve weapon systems logistics by reducing cost, improving reliability and reducing footprint (Doerr, Eaton, and Lewis, 2004). According to the Defense Acquisition University (DAU), PBL is:

> The preferred sustainment strategy for weapon system product support that employs the purchase of support as an integrated, affordable performance package designed to optimize system readiness. PBL meets performance goals for a weapon system through a support structure based on long-term performance agreements with clear lines of authority and responsibility. (Defense Acquisition University, n.d.)

The use of PBL within government has been mandated. In a memorandum dated February 12, 2002 from the Under Secretary of Defense - Acquisition, Technology and Logistics, a mandate for use of PBL is outlined. Below is an excerpt from that memorandum.

> On September 30, 2001, the Quadrennial Defense Review (QDR) mandated implementation of Performance-Based Logistics (PBL) and modern business systems with appropriate metrics to compress the supply chain, eliminate non-value-added steps, and improve readiness for major weapons systems and commodities. PBL delineates outcome performance goals of weapon systems, ensures that responsibilities are assigned, provides incentives for attaining these goals and facilitates the overall life cycle management of system reliability, supportability, and total ownership costs. (Undersecretary of Defense, 2002)

B. PERFORMANCE BASED LOGISTICS METRICS

There are five overarching metrics for PBL: Logistics Response Time, Logistics Footprint, Cost Per Unit Usage, Operational Availability and Mission Reliability. Mark Weston-Dawkes gave the following definitions and formulas in a presentation on September 26, 2006 (Weston-Dawkes, 2006).

1. Logistics Response Time

Logistics Response Time (LRT) is the period of calendar time from when a failure/malfunction is detected and validated by the maintainer to the time that the failure/malfunction has been resolved. This includes: the time from when a need is identified until the provider satisfies that need, all associated supply chain and maintenance time, and delivery time of parts.

The formula for LRT is: (Date (or time) of satisfaction of the logistics demand) minus (date (or time) of issue of logistics demand).

2. Logistics Footprint

Logistics Footprint is the government/contractor size of logistics support required to deploy, sustain and move a weapon system for a given mission profile. Measurable elements should include but not be limited to: inventory/equipment, personnel, facilities, transportation assets, supply and real estate. Measures should quantify the footprint (i.e. weight, area, volume and personnel, etc.) as appropriate.

Logistics Footprint encompasses a wide variety of elements, so one specific formula cannot encompass the entire embodiment of logistics support. However, each element can be quantified, measured, and assessed individually. These individual assessments can then be integrated as an overarching logistics footprint analysis. Logistic Footprint is a function of various elements to include area (a), volume (v), weight (w), and support personnel (sp).

3. Cost Per Unit Usage

Cost Per Unit Usage is the total Operating and Support costs, to include overhead and management costs, for a weapon system usage attributable to a given unit of usage

under established conditions. Usage can be measured in terms of unit density or individual weapons system; usage factors include miles, rounds, launches, flight hours, time, systems, etc.

The formula for Cost Per Unit Usage is (Total Operating and Support Costs) divided by (Miles/Rounds/Launches/Flight Hours, etc.).

4. Operational Availability (Ao)

Operational Availability is the percent of time that a weapon system is mission capable.

There are two possible formulas for Ao. Over any period of time, the directly measured Ao (post-fielding) is Ao=(Up Time) divided by (Up Time plus Down Time). The expected long-term, steady-state Ao (throughout the life cycle) is determined from the classic formula Ao=(Mean Time Between Failures) divided by (Mean Time Between Failures plus Mean Time To Recovery plus Mean Logistics Delay Time). It is noted that preventive maintenance and standby time must not be ignored in overall assessment.

5. Mission Reliability

Mission reliability is the measure(s) or ability of a system to achieve Operational Performance (OP) for a defined mission or specified mission profile.

The formula for Mission Reliability is (Number of successful missions) divided by (number of attempted missions). There is an alternate use of the formula, which may be used where Mission Reliability success is best measured in terms where discrete mission success does not provide best meaning for the metric. This is the formula where OP is measured as a percentage of Mission Duration. Therefore, Mission Reliability is (Total Operational Performance for Mission Duration) divided by (Total Mission Duration).

C. IMPLEMENTING PBL

1. Transition to PBL

The Department of Defense (DoD) and the Military Services are in the process of "transforming from traditional methods of logistics support to Performance-Based Logistics (PBL) as the methodology of product support for the 21st century" (Defense Contract Management Agency, 2002). According to the Performance Based Logistics (PBL) Support Guidebook issued by the Defense Contract Management Agency:

> Each PBL contract is hand crafted and will vary from other PBL contracts. PBL suppliers may take on a number of functions normally performed by various DoD services or agencies. These functions may include determining spare parts requirements, physical distribution, warehousing of material, depot level maintenance, configuration management and some engineering functions.
>
> A PBL arrangement may take many forms. There is no one-size-fits-all approach to PBL. Arrangements may be made with industry partners supporting commercially available/military unique equipment or government activities supporting military unique equipment. Also industry partners may have government activities functioning as their vendors. (Defense Contract Management Agency, 2002)

Figure 1 illustrates the full spectrum of PBL arrangements:

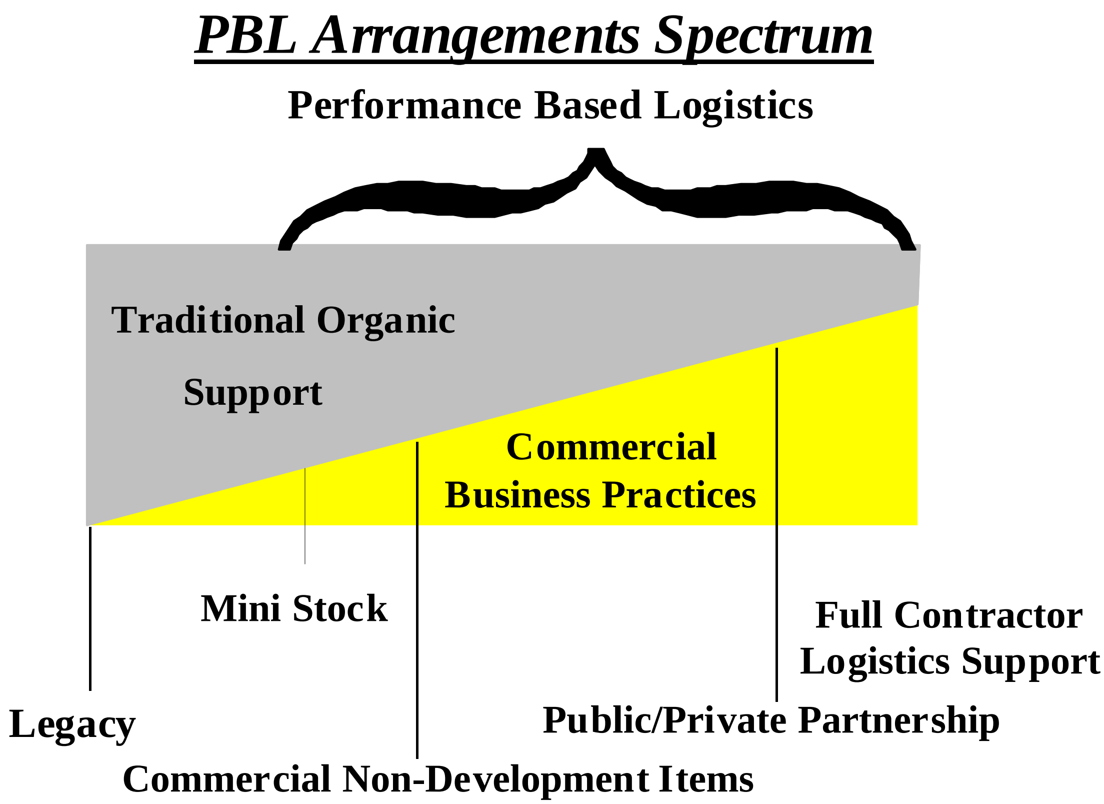

Figure 1. PBL Arrangements Spectrum (From: Defense Contract Management Agency, 2002)

Figure 2 shows the numerous factors that affect the transition of a weapons system or an entire mission area to PBL. Logistics support does not *necessarily* shift from organic DoD resources to industry resources because of the transition to PBL. However, business-DoD relationships must be structured to meet the warfighter's performance requirements. These relationships will most likely be structured differently than in the past ("A Program Manager's Guide to Buying Performance," 2001).

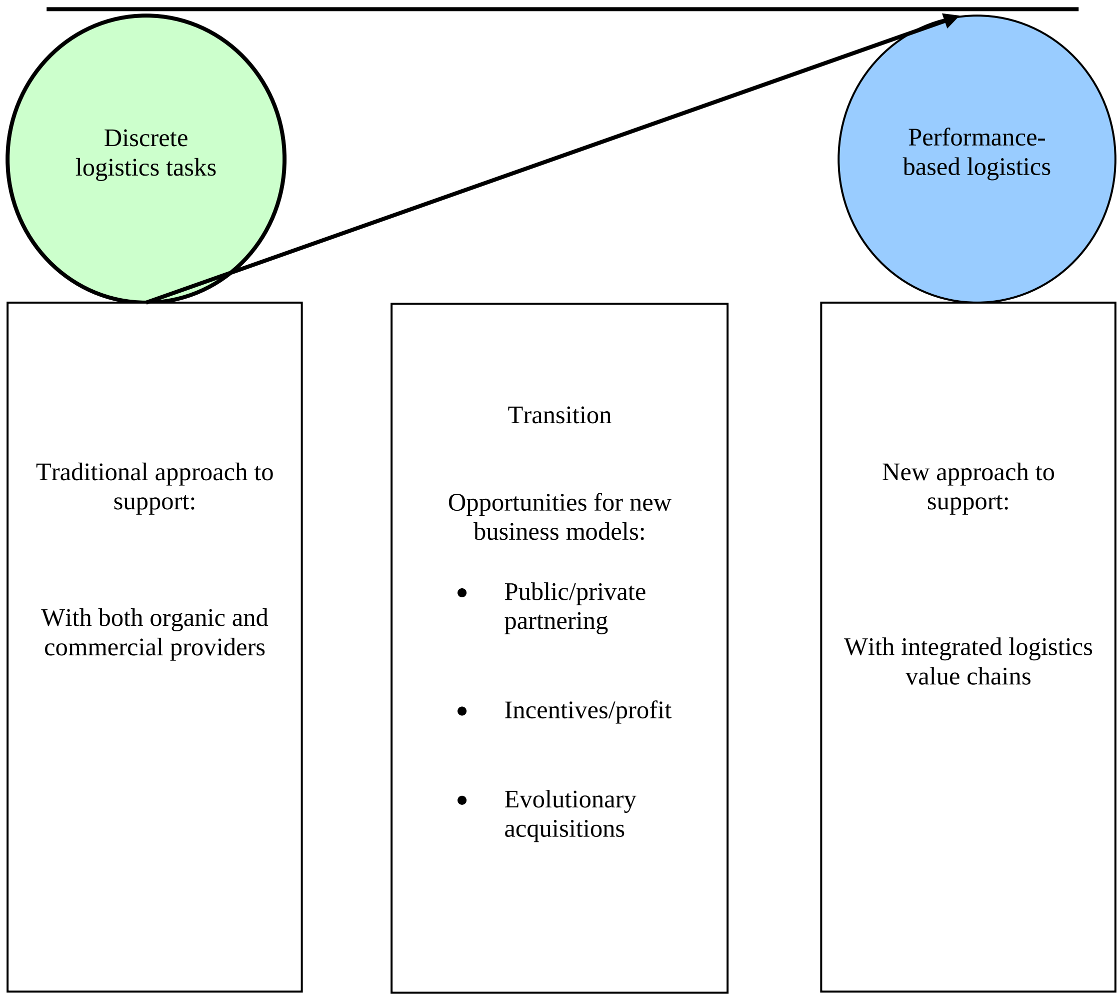

Figure 2. Transition to PBL (From: “A Program Manager’s Guide to Buying Performance,” 2001)

2. Enablers and Barriers to Implementation

Dr. Hank J. Devries conducted research relating to the barriers and enablers for PBL contracts. In his research, a data survey was created and sent out to 26 key PBL points of contact (POC) within each of the Services. The Service POCs instructed program managers who had undergone PBL implementations within their respective Services to fill out the data survey. The following figures show the results of Dr. Devries’ survey (Devries, 2005):

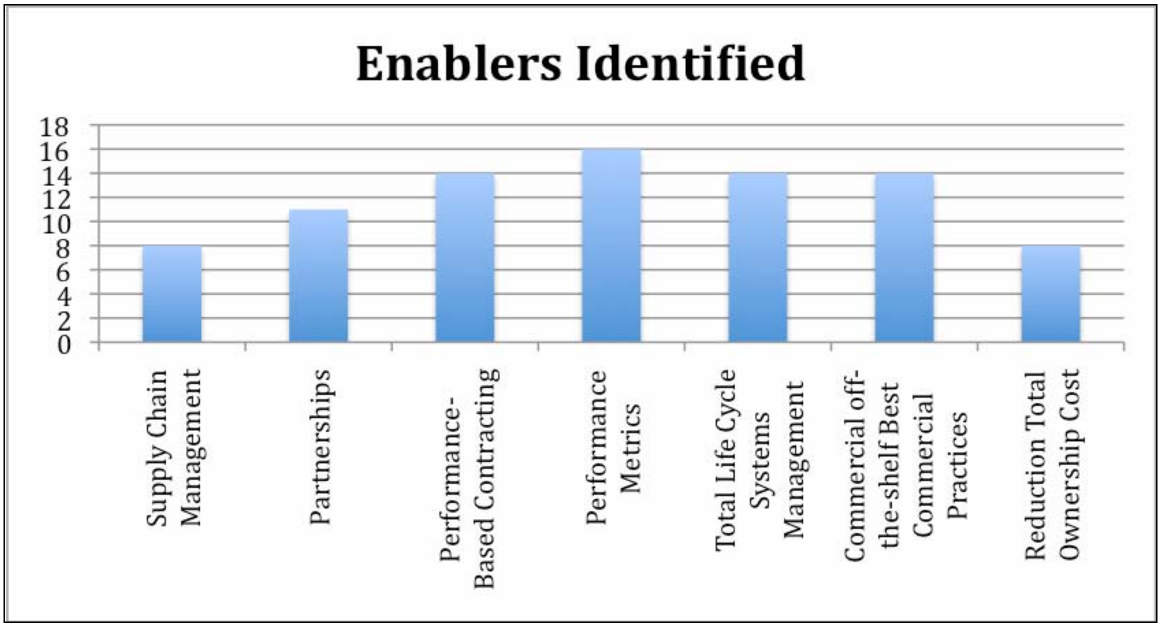

Figure 3. PBL Enablers Identified

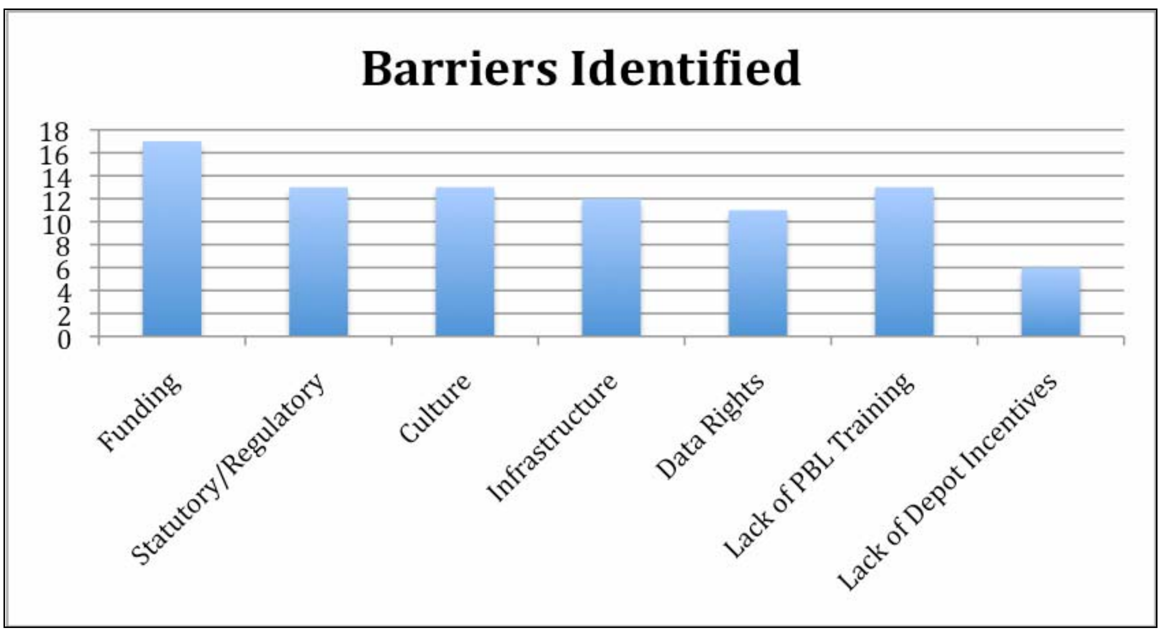

Figure 4. PBL Barriers Identified

D. PBL TRAINING AND EDUCATION

1. Online Training

DAU offers two sets of online training material for PBL. There is the DoD 5000 Tutorial and a Performance Based Logistics Training Module. The DoD 5000 Tutorial walks the student through the DoD Directive 5000.1, the DoD Instruction 5000.2 and the Defense Acquisition Guidebook. The DoD Directive 5000.1 provides the policies and principles that govern the defense acquisition system. The DoD Instruction 5000.2 establishes the management framework that implements these policies and principles. The Defense Acquisition Guidebook "is an interactive, web-based capability designed to provide the acquisition workforce and their industry partners with an instant on-line reference to best business practices as well as supporting policy, statute, and lessons learned" (Defense Acquisition University Website, n.d.).

The Performance Based Logistics Training Module is a continuous learning module. The course is based on the March 2005 DoD Performance-Based Logistics Guidebook entitled, "Performance Based Logistics: A Program Manager's Product Support Guide." In order to receive credit for the course, the student must take an exam and pass with a score of 100% (Defense Acquisition University Website, n.d.).

2. Training for Contracting Officers in the Field

The PBL training offered for contracting officers in the field is the same training that is offered online by the DAU. While speaking with those individuals working on the PBL contracts for the H-1, it appears that they have taken the online training, but have not been offered any other formal training or education on PBL. It also appears that while these individuals are experts in the field of contracting, they are not experts in the field of PBL. As previously noted, lack of PBL training is one of the barriers to implementing PBL contracts.

III. METHODOLOGY

A. RESEARCH CONTEXT

The idea for this project came from past experience while serving in Iraq. At the time, there was a general lack of understanding of why parts were not stockpiled in greater numbers, even at the sharpest end of the spear. Throughout course work and case studies in the academic setting, it became evident that inventory management was a small piece of a larger, more complex problem.

Exposure to PBL in the academic environment broadened the authors' understanding in interpreting supply/maintenance management issues. Upon examination of the H-1 Upgrade Program, a need was discovered to focus on long-term supportability of legacy systems as the fleet transitions to the new models. The intent of this project is to focus on a method to select components for PBL agreements, not to solve the total weapon system support package.

PBL as a strategy is not only required as identified in the previous chapter, but is a viable solution to preserve Ao of the legacy systems as the improved models are fielded. A good PBL established around the following attributes can sustain/improve readiness for the H-1 Program. These attributes were developed by researchers at the University of Tennessee conducting a PBL benchmarking study funded by the U.S. Air Force:

- Performance Definition. Top-level overarching outcomes maximizing readiness, availability, reliability, cycle time, and affordability.
- Performance Measurement. Minimum number of top-level 'Outcome' metrics that measure and are aligned to warfighter needs and tightly aligned with Support Provider scope of authority.
- Workload Allocation. Workloads are distributed to the most effective providers consistent with statutory guidelines, best competencies, and best value; effective use of Public-Private Partnering (PPP).
- Contract Length. Multiple year or Multi-year contract term with high confidence level for exercising options/award term years.

- Contract Type and Terms. Fixed Price with explicit or implicit incentive toward achievement of top-level system outcomes that include availability, reliability, product & process improvement and affordability.
- Performance Incentives. Incentives tightly aligned, promoting behaviors and outcomes that benefit both Customer and Support Provider.
- Product and Process Improvement. Support Provider is clearly incentivized and afforded authority to plan for and implement continuous product and process improvement (e.g., Six Sigma).
- Stakeholder Perspectives. Strong consensus across all stakeholders toward common support strategy objectives. Strong top-down support to align stakeholders for optimal solution. (Performance-based Logistics, 2008)
- These attributes focus on the outcome that warfighters desire, having the right part, at the right place, at the right time.

While implementing a PBL arrangement, the contract with the provider spells out the level of performance required by the provider in order to meet the warfighter's requirement. The description of performance is not expressed in prescriptive methods; however, it is expressed in terms of measurable outcomes. In addition, the measurement and evaluation tools and criteria are described along with the payment linked to successful performance. The purpose of the contract is to inform the contractor what the desired outcomes are, not to tell the contractor how to reach the desired outcomes. In other words, the contractor is told what to do, not how to do it (A Program Manager's Guide to Buying Performance, 2001).

While creating a performance-based contract, there are government provided resources that discuss best practices for drafting statements of work, solicitations, and quality assurance plans, and awarding and administering performance-based contracts. One of these resources is *A Guide to Best Practices for Performance-Based Service Contracting,* published by the Office of Federal Procurement Policy (OFPP) (n.d.).

According to OFPP, there are four elements that must be present in order for any acquisition to be deemed performance-based. Those elements are:

- Performance requirements that define the work in measurable, mission-related terms

- Performance standards (i.e., quality, quantity, timeliness) tied to performance requirements
- A quality assurance plan that describes how the contractor's performance will be measured against the performance standards
- If the acquisition is either critical to mission accomplishment or requires relatively large expenditures of funds, positive and negative incentives tied to the quality assurance plan measurements (A Program Manager's Guide to Buying Performance, 2001)

B. CANDIDATE SELECTION

The following section is provided to illustrate the steps taken to identify the individual component to use as basis of the authors' analysis and as an outline of their method to reach the selection of a viable PBL candidate, which they suggest be utilized by logistic managers for their PBL selection process.

Contact was made with the Director of H-1 Logistics in April 2007, in which a general question was posed pertaining to how the H-1 program was approaching PBL contracts on legacy systems. Their plan began by only considering components that Bell Helicopter managed directly, and was intended to expand from there.[2] Currently, they have PBA on eleven families containing twenty-one national stock numbers (NSNs), all manufactured and repaired by Bell Helicopter (Garvey, 2006).

As the transition from the legacy platforms begins, the challenge now for the H-1 program is to select the right candidates to pursue PBL contracts that result in improved Ao, without limiting selection to Bell-managed components.

The method the authors propose is both intuitive and critical, with thought given to PBL principles/metrics and better business practices. It considers multiple desired outcomes (described above) of reduced costs, reduced down time (Logistics Response Time), and increased Ao. The overarching goal is to select a component for which a PBL arrangement can increase reliability and maintainability. The following steps are proposed as a guide to streamline the selection process:

[2] John Baranowski, Personal interview, June 2008.

- Review Maintenance Output Reports
- PBL Matrix Fit
- Gather Additional Data/Fleet Input
- Conduct Data Analysis
- Benchmark

C. CANDIDATE EVALUATION – METHODOLOGY

1. Review Maintenance Output Reports

The primary purpose of this step is to narrow the number of components to analyze with greater scrutiny later in the process.

The report used by the authors to review usage data on the AH-1W was an Excel file provided by the H-1 IWST Director at NAVICP Philadelphia. This particular report ranked the top ten Not Mission Capable (NMC) components during the provided timeframe. The categories that the authors paid close attention to were NMC, Not Mission Capable Maintenance (NMCM), Not Mission Capable Supply (NMCS), Direct Maintenance Man-hour (DMMH), Beyond Capable Maintenance (BCM), Cannibalization (CANN), and Support Cost.

The intent is not to focus selection on one single performance category in selecting candidates for PBL contracts, but to utilize a holistic approach that encompasses all or a combination of the identified categories above.

There is potential for overlap among these categories. Components that have a negative impact on NMCM, NMCS, DMMH, BCM, and CANN all reduce the logistics response time of the end item, thus negatively impacting Ao. A component ranked high in BCM reflects a capability that the fleet does not have to repair the assets at the organic/intermediate level.

Whether it is feasible to obtain this capability by the fleet can not be answered at this level of analysis but should trigger additional consideration as a candidate. A component that is cannibalized at a high rate also deserves extra consideration.

Cannibalization is a method of survival when there are shortages; however, it is a huge indicator of waste that, if eliminated, can greatly impact Ao. The potential to double count the removal of components, thus increasing DMMH, is a danger when cannibalization actions occur.

2. PBL Matrix Fit

Within this step, the intent is to challenge the list of components by measuring their fit within the five overarching DoD PBL (system-level) metrics: Ao, reliability, cost per use, logistics response time, and logistics footprint (Weston-Dawkes, 2006).

Although the authors agree that it is important to analyze system-level metrics when considering PBL candidates, this project limits itself to component-level analysis of only two metrics: Logistics Response Time and Logistics Footprint. There are three reasons for this restriction. First, because the system-level analysis required for Ao, system-level reliability, footprint, response time and cost per unit usage is beyond the scope of the thesis, it would require the construction of an integrated system-level simulation model. Second, the authors believe that in general, component level response time (and component level reliability in particular) is a core metric that drives the other metrics. Finally, the authors believe that component footprint is especially easy to impact with outsourcing in general, and PBL in particular (Eaton, 2004).

The authors suggest that more time be spent on identifying components with poor reliability and exploring the reasons why there appears to be reliability issues (e.g., faulty design or cannibalization due to supply response time). The authors suggest that a team of experts explore the uniqueness of each component within the PBL metrics as follows:

a. Logistics Response Time

In conducting analysis, ask the following questions to determine appropriate fit for a PBL contract:

(1) Can a third party logistics (3pl) provider reduce the existing transit and repair time? A caveat to this question is, is the repair facility properly incentivized to improve the reliability of the component?

(2) If more than one repair facility is in place, can consolidation to one repair facility reduce overall LRT based on the existing supply chain management structure? The answer to this question may also have cost implications.

(3) Should the Intermediate Maintenance Facility be part of the equation or should the entire support agreement be written in order to eliminate the IMA capability for manpower re-allocation initiatives? There are both cost and long-term capability issues associated with this question.

(4) Would a PPP reduce turn-around-time more effectively than a PBL contract?

(5) What are the readiness implications associated with the current level of component reliability?

b. Logistics Footprint

Consideration must be given to the existing support structure for repair on each component. The key is to identify the possibility of reducing the footprint required without experiencing a negative impact on availability. In some cases a mixture of military and civilian personnel are necessary for proper support. Scrutiny should be given to components that already have robust facilities established for repair in which there is available capacity to exploit and where reliable maintenance is already being performed. Components that already have a small footprint, which require minimal maintenance resources, are not good candidates for a PBL.

Even though the authors are limiting their analysis to only two criteria (component response time and footprint), it is possible that these two criteria may not point to the same component as a primary target for improvement with PBL. There are accepted tools to look at multi-criteria ranking (Analytical Hierarchy Processing, simple Multi-Attribute Ranking Technique, etc.) that can be used in the process of choosing

among components to select the one that would be best served (in terms of all criteria combined) by a PBL contract. However, the use of these tools is beyond the scope of this thesis, which is limited to the analysis of a *single* component.

3. Gather Additional Data/Fleet Input

This step is rather basic yet crucial for maximized results. Contact should be made to supply support managers (MALS Supply Officers and enlisted personnel), maintenance personnel at all levels, item/inventory managers, OEM artisans, engineers, program managers, and operators of the end item.

NAVSUP in their PBL process do accomplish this task through development of Integrated Product Teams (IPT) (Garvey, 2006). These teams discuss lessons learned and issues that arise from their area of expertise in the supply/support chain. The method the authors propose is to follow this similar format, focusing on standardization and transparency for the end user.

Depending on how much resident knowledge the logistic manager possesses of the entire weapon system and its function/mission, it may be better to perform this step before step two. That is, some logistics managers may prefer to gather fleet input first, before assessing PBL fit.

4. Data Analysis

Specific data to analyze will depend on the component selected. Consideration should be given to evident trends in reliability or lack thereof. The goal in data analysis is to use near real-time information to justify logistics decisions based off actual outcomes such as increased demand, demand spike, and reduced time on wing. Again component dependent, there may be data available that reflect a reduction in availability due to supply response time or operational environment constraints.

As an example of the kind of data analysis that the authors recommend, the next chapter will conduct an analysis on logistics response time data from a single component

(a hydraulic actuator). The analysis will focus on the reliability of this component, because it has been a readiness degrader in the past.

5. Benchmark

By benchmarking, the authors are suggesting that planners should compare the processes they are considering for PBA to successfully implemented PBL strategies of other platforms/programs. Examples include the F/A-18 E/F Integrated Readiness Support Teaming (FIRST), F404 Engine, Honeywell Auxiliary Power Unit (APU), and NATO Sea Sparrow/TAS/MK-23 (Garvey, 2006).

There is no such thing as an one-sized-fits all PBL contract. Each program has different requirements and objectives. However, when looking at PBL contracts that are currently in place, there are common themes and strategies. A PBL strategy is designed with two major objectives being balanced throughout the entire life cycle of a weapon system. These objectives are that "the requirement for logistics support must be minimized through technology insertion and refreshment, and the cost-effectiveness of the logistics products and services must be continually improved." Another strategy of PBL contracts is to find the appropriate level of flexibility and agility so that the project can continue to evolve as new technology is created and the warfighter's requirements change ("A Program Manager's Guide to Buying Performance", 2001).

In addition to looking at common themes and strategies of PBL contracts, one can look to successful contracts to find proper objectives and performance metrics for their program. For instance, the United States Air Force (USAF) has a PBL contract with Boeing for the C-17 Globemaster airframe and subcomponent. This arrangement includes six performance metrics:

- Globemaster Sustainment Aircraft Availability (GSAA) is the measure of the overall health and availability of the fleet.
- Depot Scheduling is a measure of the effectiveness and efficiency of the C-17 depot maintenance program.
- Flying Hours Achievable is another metric focused on availability of the fleet and its contribution to wartime preparedness.

- Parts Issue Effectiveness (repairables and consumables) is a supply chain metric to measure how quickly the supply system delivers parts and consumables once a need is identified.
- Mission Capable (MICAP) Parts Management is a specific measure of critical parts availability.
- Customer Satisfaction is a subjective measure that gives the customer a real-time feedback mechanism and an input opportunity to contractor rewards. (Openshaw, n.d.)

Another program that can be looked at is the United States Army Shadow Tactical Unmanned Aerial Vehicle (TUAV). This PBL arrangement, scheduled for implementation in 2007, wrote the contract in order to obtain higher system availability, improved mean-time-before-system-abort, reduced logistics footprint and higher overall system readiness levels. Additionally, one can look at the USAF F-117 Nighthawk PBL contract with Lockheed Martin Corporation. This contract, awarded in 1998, included depot maintenance, engineering technical assistance, logistics support, spare parts administration and subcontractor management (Openshaw, n.d.).

This chapter has presented a general format to follow in identifying candidate components for PBL contracts, evaluating those candidates, and benchmarking successful PBL contracts on other similar components. The progression through the method suggested here by the authors is outlined in the following chapter. Although the authors will touch briefly upon candidate identification and benchmarking, their focus in the next chapter will be on the evaluation of a single component, a hydraulic actuator, in order to provide an example of the kinds of analysis they are recommending.

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IV. DATA ANALYSIS

Previous chapters outlined the methodology that the authors propose personnel follow when considering components for PBL. The purpose of this chapter is provide the framework/methodology followed in selecting the dual hydraulic actuator (NIIN 01-434-3866), in order to illustrate the recommended analysis.

A. CANDIDATE EVALUATION – PROCESS

1. Review Maintenance Reports

In June 2008, the authors visited NAVICP Philadelphia and talked with the H-1 Assistant Deputy Program Manager for Logistics (DPML) and the H-1 Integrated Weapon Support Team (IWST) Director. They provided numerous reports on the degraders for both the AH-1W and UH-1N platforms. Since the UH-1Ys are already being delivered to the fleet and the AH-1Zs are not due to start arriving at the training squadron until 2012, the authors felt it was best to focus their attention on AH-1W components where long term contracts could have greater impact on fleet readiness. Of the reports received, the one that consolidated the data best was the AH-1W top degraders from the 3rd quarter of fiscal year 2008.

AH-1W TOP TEN MAR - MAY 08 FLT HRS 10,393 10=1 CANN

WUC	DESCRIPTION	HEAD NIIN	COG	MTBF	NMC RANK	NMCM RANK	NMCS RANK	O DMMH RANK	I DMMH RANK	BCM RANK	REM RANK	AVDLR RANK	AFM RANK	CANN RANK	SUPPORT COST
1432300	DUAL HYDRAULIC ACTUATOR **	01-434-3866	7R	600	1	8	1	4		3	4	4		2	$1,436,182
1531300	MAIN ROTOR SWASHPLT/SUPPORT ASSY **	01-300-1621	7R	799	2	7	2							9	$185,426
1532100	MAIN ROTOR BLADE ASSY **	01-411-5215	7R	770	3	1						10		8	$580,265
1531100	MAIN ROTOR CNTRL SCISS/SLEEVE ASSY **	01-417-8146	7R	1,485	4	3									$302,593
1532200	MAIN ROTOR HUB ASSY **	01-408-6574	7R	371	5		8		9			3	7	10	$2,262,434
1532230	DRAG BRACE ASSY **	01-256-8197	3G	6,929	6	2								7	$4,108
29H1E30	FORWARD ENGINE MOUNT TRIPOD ASSY **	01-256-7481	3B	611	7										$136,235
1531400	MAIN ROTOR PITCH CHANGE LINK ASSY **	01-411-7075	3B	650	8	4								8	$73,733
4641300	FORWARD FUEL CELL	01-261-3082	9B	1,485	9		10								$12,397
1533340	OUTBOARD ROD END BEARING, TR **	01-166-4555	9B	1,732	10	9					8			5	$16,683
1136552	RH FAIRING ASSY	LL-CRP-V080	1R	3,464		5									$606
46431	FUEL QUANTITY INDICATOR	01-044-3479	7R	358		6								10	$38,505
29H1D80	ENGINE STARTER **	01-476-3224	7R	547		10				1	7			9	$488,268
26531	NO 1 HANGER ASSY	01-256-7479	3B	226			3				10		6	9	$277,571
29H1S12	RH EXHAUST DUCT ASSY	01-290-6522	7R	1,732			4								$1,720
1131300	GUNNER AND PILOT AREA	SYSTEM		650			5								$6,114
22100	T700 ENGINE PROPULSION SYSTEM	NA		770			6	9	2						$103,318
26540	42 DEGREE GEARBOX ASSY **	01-240-5420	7R	472			7							10	$160,749
4231C70	ANTICOLLISION LIGHT	00-686-4150	9B	168			9							5	$33,769
74N9800	SU188/AWS1(V) TELESCOP SIGHT UNIT (TSU)	01-525-5683	7R	102				5		10		2		9	$2,404,362
74N32	ELECTRONIC INTERFACE ASSY	00-578-0721	7R	1,732										4	$23,904
71RDS	C-12617/A CNTRL DISPLAY PROCESS (CDNU)	01-452-8949	7R	385						5	5			1	$105,047
653AH00	RT1558( )/APX100(V) RDR RCVR XMTR (NVG)	01-360-3841	7R	358										6	$72,064
761M200	CP1975/AAR47 COMPUTER PROCESSOR	01-495-3646	7R	1,732										10	$41,826
766S200	T-1360A(V)1/ALQ-144A(V) TRANSMITTER **	01-323-4999	7R	106					3		1			3	$206,904

Figure 5. AH-1W Top Ten Degraders

The report was ordered by NMC rank. At the top of the list is the Dual Hydraulic Actuator; however, selection was not based on this fact alone. While reviewing this report, the authors took into account that the actuator ranked 8th NMCM, 1st NMCS, 4th DMMH, 3rd BCM, 4th Removed (REM) and 2nd CANN. Another notable category was the mean time between failures (MTBF) at 600 hours. This was peculiar because past experience with this airframe revealed that these actuators had a forced removal time of 2200 or 1350 hours depending on the part that was installed. Following their holistic approach, the authors noticed that there was a good possibility that the reason this component was ranked 2nd in cannibalization was because it was also the number one supply degrader. Normally the maintenance department would not want to cannibalize this component due to mismatching part numbers. The AH-1W requires three dual hydraulic actuators to operate. Publication NAVAIR 01-H1AAC-2-5 identifies the requirement for different mounting hardware for the cyclic and collective actuators. The dual hydraulic actuators are interchangeable; however, the mounting hardware is not. Another risk in cannibalizing this component is damaging the mounting hardware in the process. Thus, from experience, cannibalizing this component could create more problems than what it is worth. The 8th ranking in NMCM does not account for the time involved in performing controllability checks via functional check flight (FCF) procedures. It also must be considered that the IMA may or may not have the capability to repair this component, as shown by the REM and BCM rankings.

As noted, the authors' approach in selecting the actuator was holistic: they looked across NMCM, NMCS, MTBF, BCM, etc., and used their experience and intuition to select a candidate for further analysis. Although they conducted no formal analysis across these criteria, the authors noted that no other WUC ranked as high across all criteria. In other words, in this case the formal analysis was considered to be unnecessary. Where the situation is less clear, or there is disagreement among stakeholders, the authors recommend using one of the many multiple-criteria decision making tools available to formally rank WUCs across criteria. This would not preclude the use of experience and intuition as well: the authors view the multiple criteria ranking tools as providing additional input, when necessary.

It is also important to note that personnel within the support pipeline may not have the resident knowledge of this aircraft; therefore, selecting the dual hydraulic actuator for further analysis may not be as intuitive. However, the authors were able to narrow the selection further by identifying that the Main Rotor Hub Assembly and Main Rotor Blade assembly were already in-work on PBL with Bell along with the other components, as illustrated in Figure 6.

2. PBL Matrix Fit

To get a better understanding of the repair process of this component, contact was made with Fleet Support Team (FST) Cherry Point in North Carolina. The authors learned that the actuator was repaired at two facilities: Singapore Technologies (ST) Aerospace in Singapore and Corpus Christi Army Depot (CCAD) located in Corpus Christi, TX. Both facilities rely on HR Textron for piece parts required for re-work/manufacturing. This information is necessary in order to evaluate the feasibility to improve Logistics Response Time and reduce the Logistics Footprint.

Nomenclature	NSN	Part Number
Gearbox Assembly	3010-01-256-7681	214-040-013-105
Indicator, Pressure	6620-01-256-8371	209-375-047-105
Fan Assembly, Hydr	1660-01-302-1006	209-040-016-107
Indicator, Pressure	6685-01-302-1006	214-175-256-105
Wing Assembly	1560-01-443-7090	209-020-004-123
Wing Assembly	1560-01-256-7640	209-020-004-107
Wing Assembly	1560-01-411-0180	209-020-004-119
Scissors & Sleeve Assy	1615-01-443-8146	214-010-501-117
Blade, Rotary Wing	1615-01-411-5215	209-015-001-105
Blade, Rotary Wing	1615-01-039-0927	209-015-001-001
Blade, Rotary Wing	1615-01-256-8268	209-015-001-101
Transmission Mast	1615-01-246-6669	209-015-001-119
Wing Assembly	1560-01-443-7060	209-020-004-124
Wing Assembly	1560-01-262-3249	209-020-004-108
Wing Assembly	1560-01-355-3907	209-020-004-116
Wing Assembly	1560-01-411-0182	209-020-004-120
Charger, Battery	6130-01-417-2165	214-175-379-105
Gyro Assembly	6615-01-083-9447	209-075-698-001
Hub, Rotor	1615-01-408-6574	214-010-100-211
Hub, Rotor	1615-01-278-3622	214-010-100-197
Blade, Rotary Wing	1615-01-173-7439	204-012-001-027

Figure 6. NAVICP Listing of H-1 PBL Candidates (From: H-1 Program Priorities)[3]

[3] Received via email from John Baranowski, H-1 Director of Logistics, May 2008.

a. Logistics Response Time

In the opinion of the authors, location of the two repair facilities is a support multiplier. Assets inducted into the repair cycle from overseas (in theatre or Japan) could be directed to the ST Aerospace facility, reducing the in-transit time. Assets inducted within the United States could be directed to CCAD. Discussion with the item manager at NAVICP confirmed that this is generally the process followed. The item manager noted the large business operations of ST Aerospace as compared to CCAD. He also said that ST Aerospace was the organization that was instrumental in solving the shortage of components available to the Navy.

The authors inquired further into ST Aerospace's role in increasing component availability. The impression obtained was that ST Aerospace and CCAD had difficulties obtaining the piece parts needed to re-build the actuators. The authors asked the item manager what exactly transpired that resolved the piece part availability to ST Aerospace and CCAD suppliers, but a reasonable explanation could not be acquired.

This issue is an area of concern for future readiness availability. Defense Logistics Agency (DLA) manages the piece parts for this component. There seems to be some sort of breakdown between DLA and the two repair facilities. A few questions to consider are:

- What measures were taken to ensure future piece part availability to ST Aerospace and CCAD?
- Could a PBL arrangement incentivize either repair facility to manage the piece parts necessary for re-work of these actuators and result in better service to the fleet?
- Were there contractual problems between DLA and its suppliers that caused the shortage of piece part availability?
- What steps were taken to avoid this problem?

At this stage of the analysis it is important for managers to explore the relationships of the entire supply chain to pin-point root causes and their effect on the overall reliability of the systems they are managing. In this case, pursuing a PBL agreement with either repair facility or the OEM, HR Textron may be in the best interest

of the United States Navy (USN). Incentives inviting these organizations to take a more active role in the re-manufacture/manufacture of these components, to include managing the inventory levels of the piece parts in lieu of DLA management, could positively impact the overall readiness of the AH-1W.

b. The Role of Reliability within Logistics Response Time

A more effective way to impact Ao, and coincidently the focus of PBL, is the realm of reliability. With a MTBF of 600 (refer to Figure 5) on the components removed during the third quarter of fiscal year 2008 and an overall MTBF on components removed dating back to January 12, 2005 of 790, reliability is clearly an issue. These components have a forced removal of 2200 or 1350 flight hours depending on which component is installed (NAVAIR 01-H1AAC-6, 2005). An assumption made here is that after 2200 hours of operation the component has a greater probability of failure; therefore, removal of this component is required. Answers to the following questions should be considered in regard to the lifetime of this component:

- Failure of what internal/external component drives the early removal?
- At what level of maintenance can the repairs be made, i.e., does the Intermediate Maintenance Activity (IMA) have repair capabilities on this component?

Contact was made with Marine Aviation Logistics Squadron-29 in New River, NC. The production control (PC) chief informed the authors that this component has a status of X1 on the Individual Component Repair Listing (ICRL). In other words the Intermediate-level (I-level) does not have repair capabilities on this asset and therefore the component is an automatic beyond capable maintenance (BCM) X1 upon induction into the repair cycle. Researching solutions or answers to why this component is not repaired at the I-level is beyond the scope of this project, but may lead to some practical low-cost solutions if the engineers and the support personnel could find the right combination of I-level and depot repair. The authors are not armed with the technical knowledge of how these components are repaired; however, they have found that a bench is currently available for the I-level to perform limited repairs and is in use at MALS-39,

Camp Pendleton, CA. Unfortunately, this capability is not available forward deployed.[4] An expansion of this capability may be the direction the H-1 community would prefer to pursue, but the authors did not research the cost implications in order to recommend a viable solution via PBL or organic means.

Additional data was obtained to explore the reliability concerns of this component. Analysis of this data will be covered in more detail under the analysis section of this methodology.

c. Logistics Footprint

Internal repair on the dual hydraulic actuator requires access to a "clean room." The purpose of a clean room to control the environment in order to minimize airborne particles that would interfere with the operation of the hydraulic actuator. When considering the current operating environment in Iraq and Afghanistan, the likelihood of obtaining a true clean room would be too costly. In this case there are some tradeoffs to consider when deciding what capability to obtain or relinquish through PPP via PBL. The design or use of existing mobile facilities for the IMA to use in partnership with HR Textron for piece part support may be worth exploring.

In this sense, a larger footprint with on-hand repair capability must be compared with the advantages and disadvantages in outsourcing this capability and making up for the response time by maintaining the proper level of spares. Currently, there seems to be some confusion at the management level as to what the minimum amount of spares for the actuator should be. The reduction of spares is another aspect of logistics footprint; however, when considering spare levels, reliability is an integral part of the discussion. Although this project does not explore reliability in great detail, the authors will provide an illustration within their data analysis of the data they received that highlights potential reliability issues of the component.

[4] Captain English, acting Aircraft Maintenance Officer MALS-39, personal communication, November 2008.

3. Gather Additional Data/Input from the Fleet

This was a continuous process throughout this project. As stated in the previous chapters, this step is interchangeable, and it may be in the interest of planners/managers to seek this information prior to accessing PBL Metrics Fit. The authors reached back to Fleet Support Team (FST) Cherry Point, the item manager at NAVICP, an airframes division chief at the squadron level, Maintenance Material Control Officers (MMCO) at the HML/A squadron and MALS Aircraft Maintenance Officer (AMO), Assistant Aircraft Maintenance Officer (AAMO), and Production Control Officer (PCO) to facilitate knowledge sharing and increase their situational awareness of the support available/required for this particular component.

4. Data Analysis

a. Creating the Model

Crystal Ball® was selected as a tool in order to provide a means to simulate the removal of components based upon the actual data received from maintenance records in the Naval Aviation Logistics Command/Management Information System (NALCOMIS) from the fleet. Simulation allows the authors to use the historical reliability data to replicate many other potential scenarios. Depicting trends in data and forecasting future events is easier to see/predict as the number of replications increase. In the authors' analysis, this software package and its output (graphs/charts) provide them with some valuable insight into the reliability of this component and enable a more accurate prediction of what the failure rates could be if the reliability of this component is improved.

The basis of the analysis was a data file received from FST that contained a snapshot of the statuses of actuators in the circulation. The data file included installation/removal dates, time on the component upon removal and the time on the components available in the supply system.

There are two part numbers for the dual actuator. The two are identical except for their forced removal times. One part number has a forced removal time of 2200 hours; the other's is 1350 hours. The authors choose to limit their analysis of the 2200-hour actuators for simplicity. The range or removal dates reported in this file is from January 2005 to August 2008. The mean time these components were removed was found to be approximately 790, with a standard deviation of 679 hours and a coefficient of variation of 0.86.

It is not strictly correct to treat the hours in this dataset as reliability data. The data are potentially censored for several reasons:

- Due to cannibalization actions, some components were likely removed from an aircraft that experienced other maintenance issues. In order to fill a hole on another aircraft that required an actuator, a fully functional actuator was removed. These occurrences could not be separated from the data set.
- Some components were removed for external discrepancies caused inadvertently by maintainers while facilitating other maintenance that cannot be directly contributed to a faulty component.
- Some components could have been removed for extensive corrosion due to environmental conditions that would reflect the lack of preventative maintenance.

Based on their personal experience, the authors believe that these occurrences are most likely few in number. However, they can affect the overall accuracy of the reliability calculations made, and so the authors cannot be sure how many of the data are censored. However, since the purpose in this chapter is only to illustrate an approach, and not to provide an exact analysis of the reliability of this part, it will be assumed that the effect of censoring on the data is not significant.

With these assumptions in mind a Crystal Ball model was developed with the intent of using the actual data in order to: 1) predict the probability that the actuator will last until 2200 hours, and 2) predict the number of hours that an actuator will reach with a 95% probability. Both of these statistics are important in building a plan for sparing the component. The first, called 'readiness risk' (Kang, et al., 2007) provides the probability that (frequency with which) a part will need to be replaced before its (current)

planned maintenance. Assuming 95% is the planned availability of the part, the second statistic provides a simple estimate of the number of hours that may be relied upon before the part needs to be replaced by a spare.

The authors also used Crystal Ball to compare these two statistics across three different distributions. Crystal Ball allows simulation of data (the building of an empirical distribution) directly from the data. In addition, it provides a tool to fit the data to several analytical distributions (such as the Normal). Analytical distributions such as the Normal, Weibull and Beta can be superior to the empirical distribution because (for example) they allow the estimation of statistics which fall outside the range of empirical observation, such as the probability that an actuator will last to 2500 hours. In addition to fitting the data to these analytical distributions, Crystal Ball tests the goodness-of-fit of the data across analytical distributions to determine which analytical distribution best fits the data. In this case, the Beta distribution was selected as providing the best fit according to the Anderson-Darling statistic. However, the Beta can assume a wider variety of shapes than most of the other distributions. There is no theoretical reason why these data should follow a Beta Distribution, and the goodness-of-fit may simply be an artifact of the sample, and the flexibility of the distribution. Hence, the authors also fit the data to a Weibull distribution. "The Weibull distribution is one of the most widely used lifetime distributions in reliability engineering. It is a versatile distribution that can take on the characteristics of other types of distributions, based on the value of the shape parameter, β" (Weibull.com, 2006). The Weibull distribution is a good fit for analysis purposes because the dual hydraulic actuator chance of failure increases as time progresses. While it did not fit the data as well as the Beta, the fit of the Weibull was also acceptable.

Results are shown in Figures 7-13. Note that the graphs in Figures 8-13 show distributions, not confidence intervals. The authors are only reporting point estimates, not confidence intervals. Crystal Ball does provide a tool for bootstrap analysis, which would allow the construction of confidence intervals for the estimates reported in Figure 6, but it was not deemed necessary for the purposes of this illustration.

Partly because the authors are only reporting point estimates, the number of 'trials' or simulated engine removals, was set at a large number (10,000).

	Initial Run	20% Reliability Improvement		
Mean	789.6	948		
Standard Deviation	679.7	679.7		
	Empirical Distribution	Weibull	Beta	20% Reliability Improvement
Forecast % to 2200	97.1	95.2	96.9	94.2
95% avail	5	63.3	11.5	141.8

Figure 7. Crystal Ball Model

b. Interpreting the Output

(1) % to 2200 - This can be read as the percentage of actuator removals that occurred in less than 2200 hours. For example, the forecast following a Weibull distribution estimates that, of the 10,000 components, 9,522 will be replaced by 2200 hours. This does not reflect an attractive reliability rate for the dual hydraulic actuator.

(2) 95% avail - This is an estimate of the number of hours of usage at least 95% of the components will have upon removal. For example, the forecast following a Weibull distribution estimates that fewer than 95% of the actuators will last beyond 63.3 hours.

The authors cannot suggest what the target level for these two statistics should be; however, from a maintenance managers perspective they would like to have a component last close to the planned replacement (2200-hour) threshold, giving them the flexibility to remove the component earlier due to scheduled/unscheduled maintenance on the aircraft that would require the removal of the components anyhow. Without a higher level of reliability, removal of these components possesses a greater strain on squadron

maintainers. As shown in Figure 10, the model using a Weibull distribution forecasts that only 4.78% (1.00 – .9522) of the 10,000 components will last longer than the 2200-hour threshold.

(3) In another iteration of the model, the authors assumed a 20% increase in the overall mean of the actuator removal times (from 790 to 948). They also assumed the same standard deviation as calculated from the original data (679.7). The 95% avail hours (95% of parts last at least this many hours) estimate increased from 63.3 to 141.8 (124% increase). However, even with the simulated 20% improvement the resulting time upon removal is anemic. As shown in Figure 13, the model using a Weibull distribution forecasts that only 5.78% (1.00-.9422) of the 10,000 components will last longer than the 2200-hour threshold. In translation, the 20% increase of the mean removal times does not equate to a 20% increase in readiness or in the overall reliability of this component. In fact, the simulated 20% increase in reliability resulted in a 1% reduction in readiness risk from 95.22% (100%-4.78%) to 94.22% (100%-5.78%). According to the analysis, even a 20% increase of the mean would still indicate that there are some potential issues with this component, whether documentation errors from removals that actually did not require removal (human error) or actual reliability concerns with the design of the actuator itself.

c. *Crystal Ball Charts*

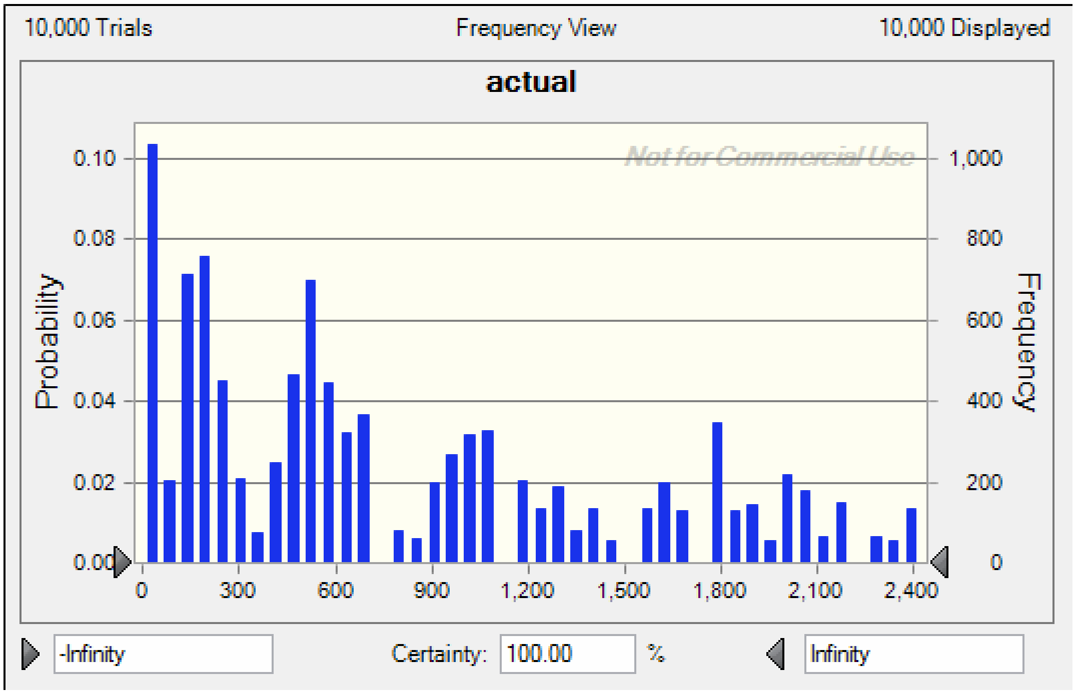

Figure 8. Actual Data Distribution after 10,000 Trials

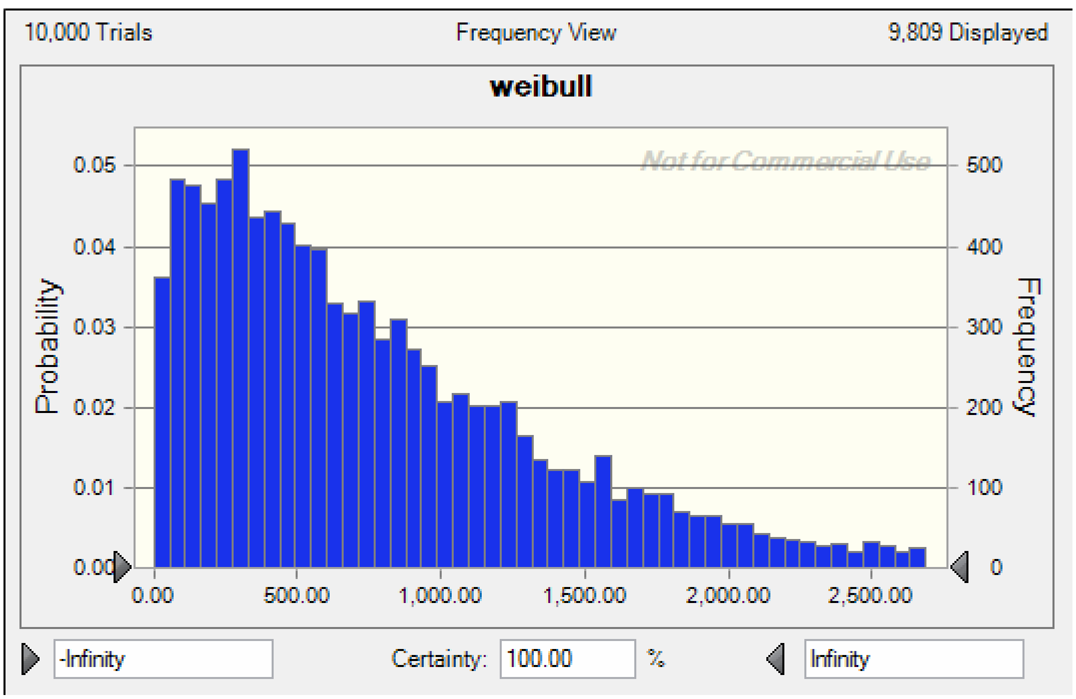

Figure 9. Weibull Distribution of Data after 10,000 Trials

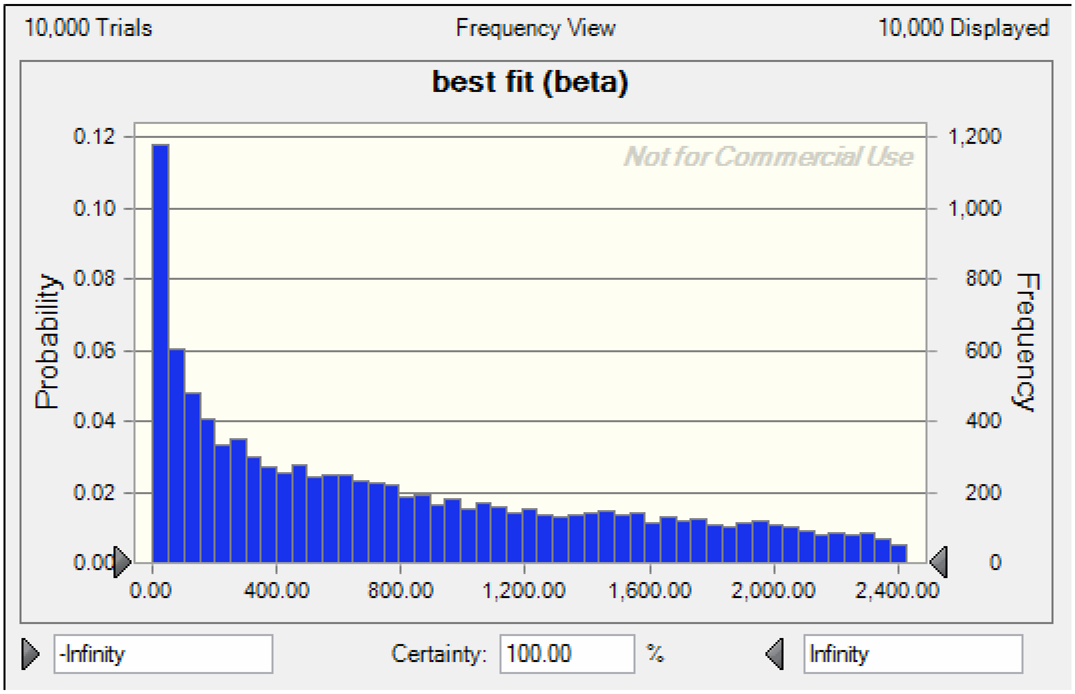

Figure 10. Best Fit (Beta) Distribution of Data after 10,000 Trials

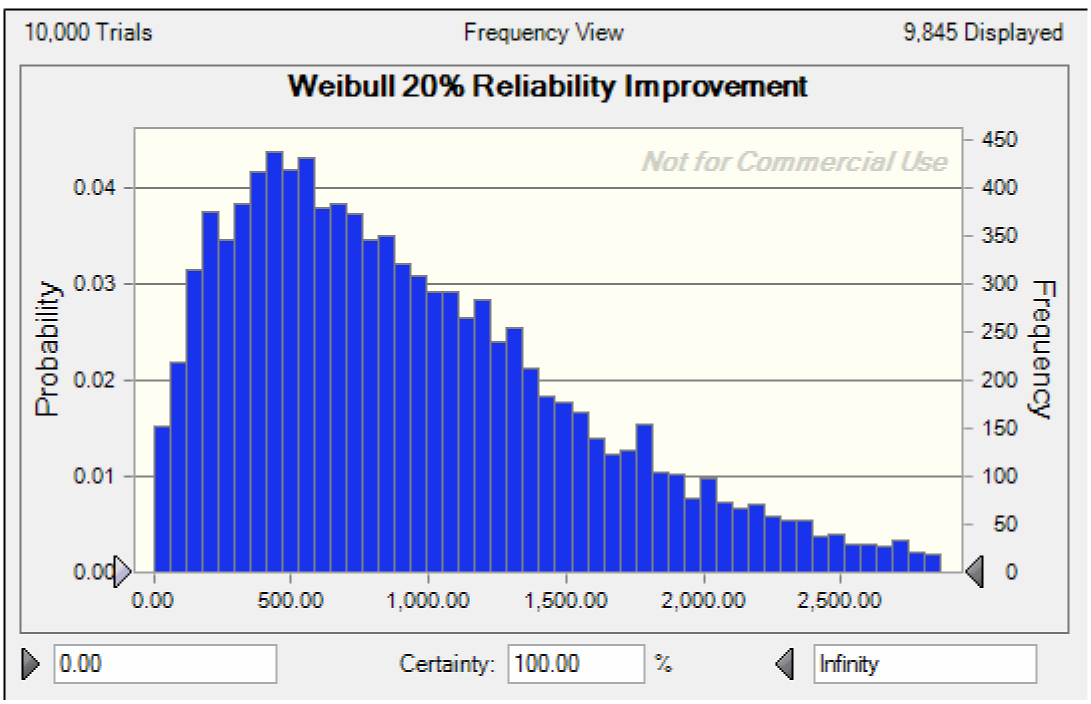

Figure 11. Best Fit (Beta) Distribution of Data after 10,000 Trials with 20% Reliability Improvement

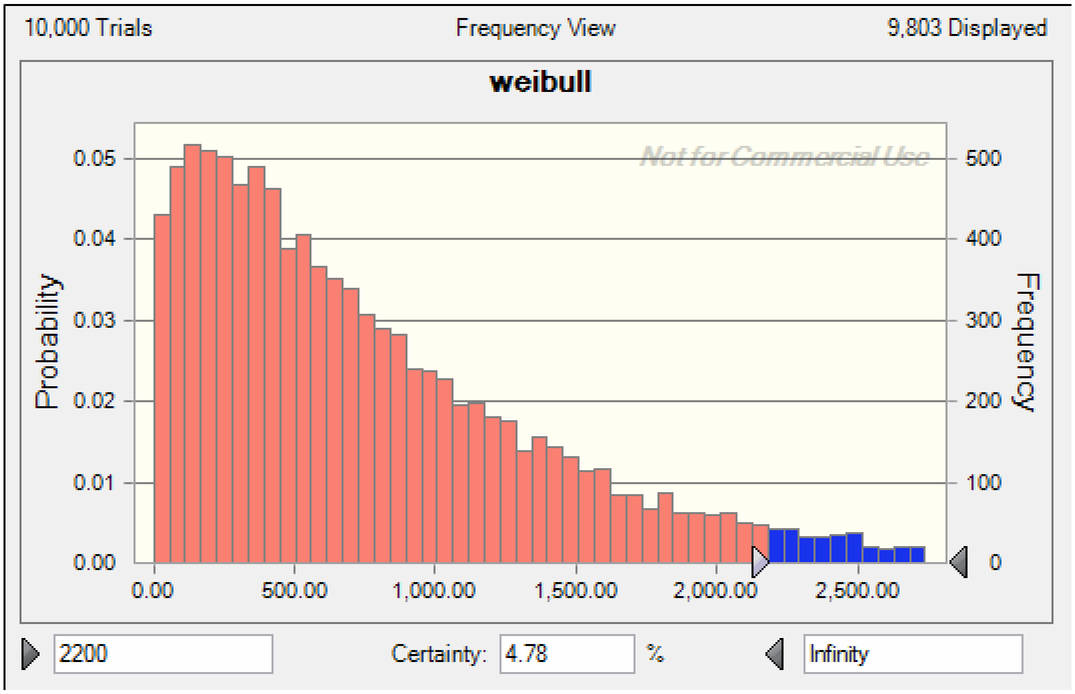

Figure 12. Weibull Distribution Demonstrating Certainty of Components Bypassing 2200 Threshold

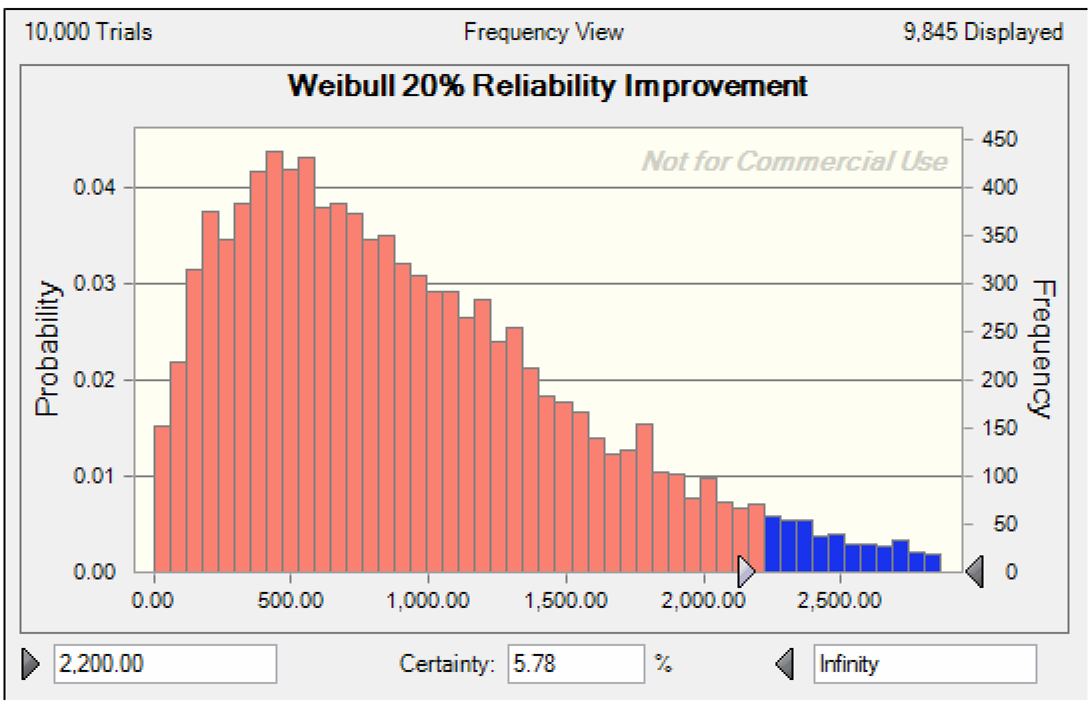

Figure 13. Weibull Distribution Demonstrating Certainty of Components Bypassing 2200 Threshold with 20% Reliability Improvement

d. Overall Analysis

The overall synopsis of the dual hydraulic actuator simulated under the authors' defined assumptions shows that there may be a significant issue with the reliability of this component. If the government is paying for this component on the assumption that it will last 2200 hours, then according to this analysis the actuator is not performing as expected.

5. Benchmarking

Benchmarking this approach against previous successful PBL programs that followed a similar approach is beyond the scope of this project. However, based on the authors' conversations with SMEs, they believe that there is a need for a more formal selection process (such as the one the authors outlined), and more formal analysis (such as the reliability analysis the authors reported upon) to develop further appropriate candidates for PBL contracts.

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V. CONCLUSIONS AND RECOMMENDATIONS

A. DISCUSSION

With one of the authors having spent numerous hours getting intimately familiar with the mechanical/supply support woes of the AH-1W airframe, but also, in the position of Maintenance Material Control Officer (MMCO) recognizing the advantages this aircraft brings to the fight, the following discussion should be considered biased in nature.

As the authors progressed through this project, three common themes seemed to surface when involved in discussion with outside sources:

- People are not talking to the right people. The DoD is full of bright, motivated personnel, both civilian and military, who want to make a difference and provide the best product or service to the warfighter. The problem, though, is the inherent bureaucracy of the DoD, which functions as a barrier to discovering the critical links necessary to identify and solve problems.
- Management personnel outside of the operational forces generally have a working knowledge of PBL. However, at the operational level there seems to be a lack of training and understanding of what PBL entails, let alone what information decision makers need to make the right choice for PBL candidate selection. Drawing from past experiences where the focus was on mission capable airplanes and chasing the parts required to maintain those airframes, having the understanding that the answer to those issues is not just in inventory levels, but also on reliability of the airframes and their components could have resulted in a greater contribution to the operational readiness of the AH-1W today.
- PBL culture does not exist within DoD at the broader spectrum that is required to successfully introduce PBL to a program. In the authors' opinion, inventory/maintenance managers focus too much on meeting demand and forecasting future requirements based on previous demand instead of discovering other solutions (i.e., reliability). Questions should be posed as to why these parts are failing as opposed to how to obtain more of these parts. Despite the direction from Congress to utilize PBL as the primary contracting tool for DoD acquisitions and programs, the culture of DoD is slower to shift from obtaining higher inventory levels to mitigate part shortages to focusing on reliability/maintainability of the

components to improve operational availability. In order for inventory/maintenance managers to enter into the PBL mindset, they need proper training and education.

B. PROJECT SUMMARY

The purpose of this study was to provide a background of the H-1 program and performance based logistics and to ultimately find a methodology that would enable contracting personnel to select and analyze components that are good candidates for PBL contracts within the H-1 program.

The H-1 community has existed since the Vietnam era and the latest upgrade contract was issued in 1996. Currently, DoD has a PBL contract with Bell Helicopter Textron, Inc. PBL contracts are the preferred method of acquisition within DoD and currently there are PBL contracts on eleven families containing twenty-one NSNs. However, there is no standard methodology used to select and analyze components which are to be used in PBL contracts.

In order to determine which component was a good candidate for further exploration, the authors gathered data from NAVICP Philadelphia including reports listing the top ten NMC components. The authors then looked at the NMCM, NMCS, DMMH, BCM, CANN and Support Cost categories to select the component for further evaluation. The component selected was the dual hydraulic actuator.

The authors used reports listing the removal hours on each of the dual hydraulic actuators. The data was entered into a Crystal Ball model. This model used the actual data to forecast the removal time for 10,000 of these parts. Using the results from this model, in conjunction with knowledge and experience about the aircraft and this component, the authors were able to make conclusions regarding the dual hydraulic actuator and whether or not it is a good candidate for a PBL contract.

C. CONCLUSIONS

1. Analysis Supports Non-critical Pre-mature Failure of the Dual Hydraulic Actuator in Comparison to its Life Expectancy

Using the forecasts from the Crystal Ball model, the authors conclude that the dual hydraulic actuator may not perform at its expected level. Less than 5% of the parts are forecasted to remain functional until the 2200-hour forced removal threshold. In addition, the average removal time of the component is 790 hours. Based on their assumptions and while considering the limitations the data presented, in the authors' opinion it is still reasonably safe to assume that there are reliability issues with the actuator that may be worth addressing though PBL means.

2. PBL Contracts are an Appropriate Tool to Use

DoD has mandated the use of PBL contracts in situations where their use is appropriate and applicable. For the H-1 program, specifically the dual hydraulic actuator for the AH-1W, a PBL contract written with an acceptable reliability requirement and streamlined support structure, whether via IMA or contractor support, can reduce downtime and increase operational availability.

D. RECOMMENDATIONS

1. The Dual Hydraulic Actuator Should be Considered a Candidate for a PBL Contract

After looking at the data provided by the Crystal Ball model, the authors recommend that the dual hydraulic actuator be awarded a PBL contract. At this point, there is a need to increase reliability, which in turn will have an impact on the operational availability of the AH-1W. However, the system-level impact is difficult to measure and it is important to note that focusing on the reliability of one component such as the dual hydraulic actuator is not the end-all solution to increased Ao.

2. Data Analysis Should Include Alternative Analytical Tools in the Absence of Access or Understanding of Crystal Ball

Crystal Ball is an extremely useful tool and provided adequate forecasts for the purpose of this study. In addition to Crystal Ball, there are other tools available such as software from Real Options Valuation that can be used to create a similar and/or more sophisticated model than was created with Crystal Ball. However, even without these tools, it seems clear from the results that some sort of analysis of the variance in (or distribution of) part reliability, and not just an analysis of the mean time to failure, should be incorporated into PBL candidate review.

3. Increase PBL Training Opportunities

While PBL is the DoD's preferred method of contracting, it appears that there is limited, if any, training for those individuals who are using this tool. In the authors' opinion, successful PBL implementation relies on the integration of technical expertise from fleet operators and maintainers of these systems. PBL training must also reach out to acquisition personnel to be more readily prepared to recognize the potential benefits a PBL contract/arrangement could bring to the war-fighter.

E. OPPORTUNITIES FOR FURTHER STUDY

1. Conduct Similar Study Using Gathered Data from the H-1 Reliability Centered Maintenance (RCM) Program via L-3 Communications

The authors were unaware a RCM program existed for the H-1 program until the very end of their project. The RCM program has what they call "over the shoulder" data collection on reliability of components. While gathering data, the authors made assumptions regarding the data provided. Fewer assumptions would be necessary if the data being analyzed came from the RCM program before their information was sent directly to engineers when reliability issues are identified. A research project working hand and hand with this entity may result in a better streamlined process to follow for PBL candidate selection.

2. Research Other Components

The authors only looked at one component, the dual hydraulic actuator, in this study. However, using the methodology presented in this study, other components should be looked at to determine if they are also good candidates for PBL contracts.

3. Determine the Best Metrics to Use in These PBL Contracts

Although the authors looked at benchmarking to generate themes and ideas for metrics in the PBL contract, exact metrics are needed. In addition to the traditional PBL metrics, the authors propose that their metrics related to readiness and risk, as discussed in Chapter IV (Data Analysis), be added to the evaluation process of PBL contracts. The contract needs to incentivize the contractor for the appropriate metrics. In order to do this, research is needed to determine the cause of the premature failure of this and other components belonging to the AH-1W or any DoD system.

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